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ABSTRACT

This report describes a program for developing and improving critical thinking skills in adolescents in order to prepare them for life-long learning. The targeted population consisted of high school math and social studies students from two middle-class communities located in northern Illinois. The students' lack of critical thinking skills was documented through data collected from teacher, student, and parent surveys, and the Cornell Critical Thinking Test - Level X. Analysis of probable cause data revealed that teachers believed that they taught critical thinking skills to their students. Likewise, students indicated that they, too, felt that they were asked to think critically in their classes. However, data from the Cornell Critical Thinking Test indicated shortcomings in the students' ability to think critically. A review of current literature indicated that many teachers are not properly trained to teach and assess critical thinking, even though they believe they are. A review of solution strategies suggested by noted experts in the field of critical thinking, combined with an analysis of the problem setting, resulted in the selection of materials, language, and learning activities that stimulated the students' critical thinking habits in both mathematics and social studies. Post intervention data indicated an increase in student use of the targeted critical thinking skills as measured by the Cornell Critical Thinking Test - Level X. (Contains 35 references.) (Author/WRM)

IMPROVING CRITICAL THINKING SKILLS IN SECONDARY MATH AND SOCIAL STUDIES CLASSES

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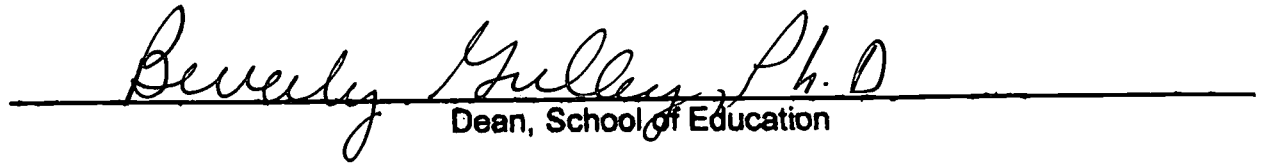

Dean, School of Education

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CHAPTER 1

PROBLEM STATEMENT AND CONTEXT

General Statement of Problem

The targeted high school students exhibit a lack of critical thinking skills in math and social studies classes. Evidence for this problem was gathered from the following data: teacher, parent, and student questionnaires and the Cornell Critical Thinking Test - Level X.

Immediate Problem Context

Site A

The student community of Site A is composed of approximately 1,265 young women from uniquely diverse backgrounds. Currently, the population is 75% White non-Hispanic, 14% Hispanic, 9% Black non-Hispanic, and 2% Asian. The present population is 89% Catholic. Students come from over 200 different grammar schools with 71% coming from a large midwestern metropolitan city and 29% from its neighboring suburbs. Almost 91% of the students live more than a mile and a half from school. Approximately 58% of the students are driven to school in privately owned cars or in car pools, 35% use public transportation, and 6% use a privately owned bus service (Office of Catholic Education Secondary School Survey, 1997).

According to a 1993 school survey, the mean family income is between $36,000 and $45,000 with the majority of parents possessing a high school diploma. Approximately 25% have completed only grammar school while an additional 25-30% have completed some

degree of post-secondary education. Many parents are employed in blue collar and service professions.

The Site A adult community serving these students includes a principal, assistant principal, two associate administrators, three curriculum coordinators, four counselors, a career guidance advisor, four deans, a student activities director, an athletic director, and 87 full or part-time teachers. Since no one person serves as department chair, teachers at Site A share duties within the department. All department responsibilities, which include budget, mail, facilitating meetings, taking minutes, and representing the department on the scope and sequence committee, are distributed by the administration to various members of each department.

The professional staff is 98% White non-Hispanic, 1% Black non-Hispanic, and 1% Hispanic with 92% female and 8% male (Office of Catholic Education Secondary School Survey). The professional staff possesses an average of 10 years of teaching experience and have educational backgrounds ranging from those of recent college graduates to those pursuing doctoral work, with 63% having attained a master's degree. The average teacher's salary is $28,800.

The support staff includes an attendance director, technology director, technology assistant, instructional technology coordinator, librarian and library aide, full-time nurse, two full-time substitutes, a treasurer, business manager and assistant, tuition officer, three administrative secretaries, and two receptionists. The entire community is supported by a full-time development staff that includes a director/grant writer, major funds developer, institutional advancement director, public relations director, four recruiters, and one full-time and one part-time secretary. Also serving the school community are eight full-time and two part-time custodians and contracted food services personnel.

The targeted Site A secondary school, built in 1964, is located in a single two-story building that contains 61 classrooms, a gymnasium, cafeteria, retreat center, chapel, guidance center, small theater, several multi-purpose meeting rooms, and various types of administrative offices. In addition, the building is designed to accommodate fine arts and physical education programs, business education classes and interdisciplinary programs, as well as regular academic programs. The library is equipped with five internet access stations and Proquest, an electronic periodical index. The facility has recently been updated to include a fitness center available for use by the entire school community. The three computer labs have been upgraded with 105 networked pentium computers. Two new high-tech science labs, constructed over the summer, are each equipped with eight computers and two printers, a video recorder with surround sound stereo, an overhead projector hooked up to a computer terminal, and computer programs that enable students to do computer interfaced lab experiments. This last update also completed Phase I of the Facilities Plan presently underway.

As members of this community, each student engages in a college preparatory curriculum. Students must complete 17.5 core credits and five elective credits to meet graduation requirements. These credits must include four years of Christian living/religious studies, four years of language arts, three years of social studies, two years of a lab science, two years of mathematics, two years of either Spanish or French, and one semester each of computer applications and fine arts, i.e., art, chorus, dance, or drama. Two years of physical education is required as well. In addition, a minimum of 60 community service hours is essential for graduation. Also, approximately 94% of the senior class takes the ACT test with those students achieving an average composite score of 20.0.

The average daily attendance rate for the 1996/97 school year was 97%. This high daily attendance rate may have been positively impacted by the full-time attendance

director, individual class deans, and a voice mail system that was added during the 1993/94 school year. The dropout rate is too small to record and there are no chronic truants. The calculated cost per student is $4,470. Funding to cover this cost comes from a variety of sources including tuition, mandatory student fund raising, auxiliary enterprises, development income, and investment income. Approximately 10% of the students receive some amount of financial aid. Generally, the withdrawal rate for each class from first year to graduation is 15% with the major reasons given for withdrawal being relocation or financial burden (North Central Report, 1995).

The targeted school at Site A stresses its identity as a Catholic community on a day-to-day basis. The school is privately sponsored by a religious order of women and is governed by a two-tiered Board of Directors. The religious order promotes the identity of a Catholic school where values such as truth, compassion, scholarship, community, and a passion for peace and justice are an integral part of the curriculum. The administration solicits teacher input regarding many educational decisions because "teacher ownership" is inherent in the school's philosophy. As a result, there is a good working relationship among the administration, board, and faculty.

Further, the professional staff shares a commitment to learning and to providing each student with the opportunity for success. Ongoing professional development inservices for faculty attest to the school's dedication to educational excellence. Within the classroom the faculty, through interdisciplinary courses, team teaching, peer coaching, and frequent collegial consultations, provide students with an optimum learning experience. The professional dedication of the faculty is exemplified by their willingness to take graduate or technology courses at least every three years. Their commitment is affirmed by the administration who also provides each faculty member with two paid days for professional

development each year. This serves as strong evidence that the school's personnel are committed to life-long learning and the refinement of their teaching practices.

The belief that technology enhances the curriculum is apparent in the recent hiring of an instructional technology coordinator, the updating of the computer labs, and the application for a Tandy Grant to increase and improve the use of technology in mathematics classes. In addition, the belief that learning transcends the classroom is reflected in the encouragement of field trips and in the numerous extra-curricular activities, many of which include service and leadership training as integral components of these experiences.

Finally, each year members of the faculty meet with students on an individual basis to help them assess their progress and choose the most challenging curriculum for the following year. The belief that students must be prepared to assume their places as leaders of the future demands that they be given opportunities to excel both in and outside of the classroom. Teachers, class and club moderators, coaches, and counselors provide students with the encouragement to try, the opportunity to learn from their mistakes, and the confidence to try again. Growth, maturity, compassion, and insight are the visible results, results which are acclaimed through the publishing of the quarterly academic and service/leadership honor roll, yearly awards assemblies, and seasonal sports banquets. When seniors respond to an annual survey, they consistently indicate their positive relationships with teachers as their most vivid memory of the school.

Overall, the school operates from a perspective that invites students with a range of abilities to thrive in a non-tracked, non-labeled environment. While approximately 92% of the students are college-bound, the school also offers programs for students who may not immediately go on to college because it is the school's belief that all courses are beneficial regardless of the students' immediate plans. All courses are intended to be challenging and it is each student's choice of non-required courses which tailors her program to suit her

personal interests and needs. However, the school does not have a program for students who experience significant motivational difficulty in the classroom or who have specially diagnosed learning needs. As a result, such students are not usually accepted for enrollment.

Site B

The Site B targeted student community is composed of approximately 2,232 adolescents from several neighboring suburbs. The racial/ethnic background of the students is 92.7% Black non-Hispanic, 3.0% White non-Hispanic, 3.7% Hispanic, 0.4% Asian/Pacific Islander, and 0.2% American Indian. Most students come from four or five feeder schools in the immediate area; however, some students transfer from other schools due to a change in residence. Approximately 56.5% of the students come from low-income families, i.e., either these students are from families receiving public aid or are living in institutions for neglected or delinquent children; still others are being supported in foster homes with public funds. Many are also eligible to receive free or reduced-priced lunches. Students having limited English proficiency comprise 1.1% of the student body. These students, who have been labeled Limited-English-Proficient, are eligible for bilingual education (School Report Card, 1997).

The faculty serving this targeted Site B school consists of a principal, four assistant principals, four deans, seven counselors, a career counselor, a student activities director, an athletic director, an assistant athletic director, two social workers, a speech pathologist, a psychologist, an audio-visual technician, two attendance directors, and 139 full or part-time teachers. Some of these teachers serve as department chairs. They teach fewer classes and their additional duties include scheduling, developing agendas for department meetings, taking minutes at those meetings, and handling budget and incoming mail.

As to the racial/ethnic background, teaching experience, and educational background of the staff, the district numbers are more relevant than those specifically for the Site B school because teachers can move around within the three schools in the district as the need arises. The professional staff in the district is 78.1% White non-Hispanic, 21.3% Black non-Hispanic, 0.4% Hispanic, and 0.2% Asian/Pacific Islander with 54% female and 46% male. The faculty possesses an average of 16.7 years of teaching experience, with 64.3% having attained a master's degree or higher. A first year teacher with a B.A. receives a salary of $32,000 while the average teacher's salary is approximately $61,261 (School Report Card, 1997).

The targeted Site B secondary school is located in three buildings. One building contains the administrative offices, numerous core academic and special programs classrooms, departmental offices, student and faculty cafeterias, guidance center, one large auditorium, and a small theater. The second building contains health and physical education facilities, including gyms, swimming pool, weight room, wrestling room, and mirrored room for dance. The third building houses the vocational educational programs classrooms which include shop and auto mechanics. There are also fully equipped, internet accessible, computer labs, one of which is housed in the library.

Students at this school must complete 17 academic credits to meet graduation requirements. These credits must include four years of English, four years of PE, and three years of applied and/or fine arts. Applied arts include business education, home economics, industrial technology, and occupational training while fine arts consists of art, foreign language, music, and speech. Also required for graduation are two years of math, two years of science, two years of social science, and one semester each of health and consumer education or economics. Service hours are not required for graduation; however, many

extra-curricular activities provide students with opportunities to perform community service. The graduation rate is 69.3%, a rate which is about 12.3% lower than the state rate. Approximately 23.7% of all students who complete the core high school program opt to take the ACT test. Their ACT composite score is 18.9 compared with the state ACT composite of 23.0.

The average daily attendance rate at Site B is 89.3%. The dropout rate is 4.2%, a rate which is 2.2% lower than the state dropout rate for the 1996-97 school year. There is a chronic truancy rate of approximately 1.7%. Using eighth grade IGAP scores, the school requires that those students who do not meet the math and/or English requirements for entering freshman year be placed in the appropriate Acceleration Program. This is a program in which specially trained teachers use quantum learning, cooperative learning, and multiple intelligences to help those students improve their math and/or English skills. Students may enter the first year curriculum upon successful completion of this program. The calculated cost per student at Site B is $10,465 (School Report Card, 1997).

The Surrounding Community

Site A

The community surrounding Site A is a suburb of a major midwestern metropolitan city. This area is bounded by several smaller suburban communities. The 1990 census indicates the current population is 27,600 with 94.2% White non-Hispanic, 4.7% Hispanic, and 1.1% Asian. The community has no Black non-Hispanic residents. The population is primarily comprised of middle class blue collar families.

The area businesses are primarily small independent operations, but adjacent to this community is an industrial area that contains several major corporations. The school and community have had a limited relationship, but through service activities and outreach programs this relationship is expanding. For example, students have been encouraged to

volunteer time to local service organizations; businesses have been encouraged to establish professional contacts with students and maintain those contacts after graduation. In addition, the school issues press releases to local newspapers highlighting student achievement. Further, community officials and business owners from the area have been invited to informational meetings at the school and to the yearly parent/board/community visitation day. Also, in the past two years the school has recognized and honored members of the surrounding community who have had a positive influence on the students. Finally, the school is also a member of the local Chamber of Commerce and the Clergy Association.

Neighboring this all girls' school is a privately owned Catholic all boys' high school. In the past, the relationship between these two institutions has been very limited, but the current administration of both schools have been working to expand and strengthen this relationship. Currently there is a strong band program that unites the two schools. This combined band has won numerous local, state, and international awards and has performed at many functions at both schools. Finally, the local public high school works in cooperation with this targeted school in obtaining Title I Eisenhower Grant funds.

Site B

The targeted Site B school is located in a suburb of a major midwestern city. This area is surrounded by several other suburbs of similar size. The Site B school is the only high school in this suburb; however, there are several public and private elementary schools. According to the 1988 census of area and population characteristics, the population of this suburb is 35,370. The racial/ethnic make-up of the community is 31.6% White non-Hispanic, 65.6% Black non-Hispanic, 4.6% Hispanic, .18% Asian/Pacific Islander, 0.2% American Indian/Eskimo/Aleut, and 0.1% other. Like Site A, this community is primarily comprised of middle class blue collar workers.

The Site B school is directly surrounded by a residential neighborhood. Within a two mile radius of the school there are numerous small fast food restaurants and other smaller businesses. There are no national chain restaurants or grocery stores in the area. A major expressway is located within three miles of the school. This expressway allows for easy access to the nearby metropolitan city. There are also many churches of different denominations within the community.

Also, not unlike Site A, there is a limited, but growing, relationship between the community and the targeted school. For example, community businesses and churches donate prizes to be used at various school activities, send representatives to school activities such as the school health fair, and work with the staff to assist students in developing their values and morals. Also, students are encouraged to volunteer within the community and many work for community businesses.

Regional and National Context of Problem

Critical thinking is essential to effective learning and productive living. According to Richard Paul (1995), two things are crucial in defining critical thinking:

> 1) critical thinking is not just thinking, but thinking which entails self-improvement and
>
> 2) this improvement comes from skill in using standards by which one appropriately assesses thinking. (p. 91)

In most secondary schools today, research seems to indicates that students' lack of critical thinking skills is not being adequately addressed in the classroom. Many educators feel such pressure to completely cover the content of their curriculum that they feel there is not enough time to teach critical thinking skills. Also, many educators shy away from teaching critical thinking skills simply because they feel inadequately prepared to do so. In *A Nation at Risk* (1983), the National Commission on Excellence in Education recommended that

formal instruction in critical thinking skills be mainstreamed across the curriculum at all levels. This definitive report on the nation's schools asserts:

> Many 17-year-olds do not possess the "higher order" intellectual skills we should expect of them. Nearly 40 percent cannot draw inferences from written material; only one-fifth can write a persuasive essay; and only one-third can solve a mathematics problem requiring several steps. (p. 9)

In order to address these concerns so that all members of society can prepare for the ever-changing competition and conditions of the workplace, we must offer students opportunities to attain content goals through critical thinking strategies. This belief, that the teaching of critical thinking skills should be a priority in our classrooms, was affirmed by 80% of the educators polled in a Gallup Poll of Teachers' Attitudes Towards the Public Schools (1989).

However, educators are not the only individuals concerned about students' lack of critical thinking skills. This concern, according to professors Nidds and McGerald (1995), is reaffirmed by the results of a 1995 questionnaire they sent to the chief executive officers of "Fortune 500" corporations. In response to the question "What academic skills should our schools teach to prepare students for the twenty-first century?" these CEO's all emphatically responded that the teaching of analytical, logical, higher order, conceptual, and problem-solving skills are vital if the country is to remain globally competitive.

Interestingly, current educational research suggests that people are not born with critical thinking skills but must be taught to think critically. Historically, the teaching of thinking skills has been approached in two different ways: Explicitly teaching thinking in isolation or teaching critical thinking within content areas. However, research seems to

indicate that the most beneficial way to prepare students to think critically is to infuse explicit teaching of those skills into the content areas (Perkins as cited in Costa, et al., 1992).

First, however, teachers must be trained explicitly to teach thinking skills to students in their content areas. For example, they must challenge students to learn not only content but also the skills necessary to process and transfer that information. Reinforcing the need for such teacher training is the fact that CEO's indicated they feel students entering the workforce today are dramatically lacking in higher-level thinking skills, the ability to diagnose and solve problems, the ability to apply their skills to new and unfamiliar problems, and the ability to work effectively in groups (Nidds and McGerald, 1995). Finally, research suggests that cooperative groups may be an appropriate setting in which to accomplish these goals (Cameron as cited in Costa, et al., 1992).

CHAPTER 2

PROBLEM DOCUMENTATION

Problem Evidence

In order to document the lack of critical thinking skills in high school math and social studies students, the Cornell Critical Thinking Test - Level X (Ennis & Millman, 1985) was administered to the targeted students at sites A and B during the first week of the school year. In order to allow students sufficient testing time, the researchers modified the administration of the test. Instead of students taking the entire test during the single class period for which it was designed, the test was given over a three-day period. Section I was administered the first day, Section II the second day, and Sections III and IV the third day. The researchers decided to modify the test administration for the following reasons:

- to overcome the time constraints imposed by class periods in a high school setting
- to limit the amount of reading required to be completed in a class period since some of the targeted students have a low reading ability
- to provide adequate time for students to process the information given
- to reduce the amount of test anxiety.

The Cornell Test (Appendix A) was chosen by the researchers because it is one of the few standardized tests that can be used to assess the critical thinking skills of high school students. The Level X version of the test contains 71 multiple-choice items and is

aimed at students in grades four through fourteen. This test is described by its authors as a general critical thinking test since it is intended to assess critical thinking skills as a whole. The four major areas of critical thinking on which the test focuses are induction, credibility, deduction, and assumption identification. In the induction section of the test, students are expected to judge whether or not a given fact supports the given hypothesis. Then, in the credibility section, students are asked to decide which of two given statements is more believable under the given circumstances. Next, students are required in the deduction section to decide what must follow from given information that is assumed to be true. Finally, in section four, the students must decide what ideas are taken for granted in given statements. Ennis and Millman (1985) indicate that ideally, a general critical thinking test would also cover attitudes of a critical thinker such as open-mindedness, caution, and valuing being well-informed. However, they admit that it is very difficult to test for such attitudes.

Researcher 1, from Site A, administered the Cornell Test to tenth grade students, identified as having low math ability, all of whom are participating in the second year of a two-year algebra program. Researcher 2, also from Site A, administered the test to ninth and tenth grade students in an honors geometry program. Researcher 3, from Site B, tested eleven and twelfth grade students in American law classes. These students are heterogeneously grouped.

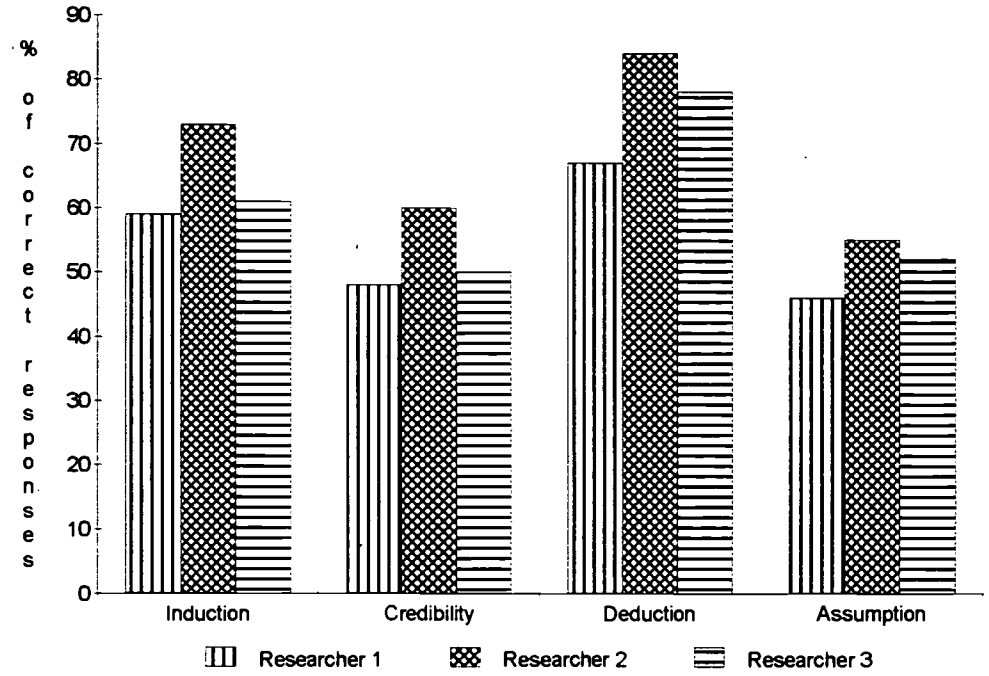

Figure 1. Results of the Cornell Critical Thinking Test - Level X for the targeted classes administered the first week of the 1998-99 school year.

As indicated in Figure 1, the targeted students correctly responded to questions that required inductive reasoning with a combined accuracy rate of 64%. In addition, the students responded correctly to questions requiring deductive reasoning with a combined accuracy rate of 75%. However, in section two of the test, which required students to judge the credibility of an assertion, the students combined accuracy rate was only 53%. And in part four, which required students to identify reasonable assumptions, their combined accuracy rate was just 51%. Figure 1 also indicates that the students identified as high ability students consistently performed higher on each section of the Cornell Critical Thinking Test than the students who were heterogeneously grouped or designated low ability. Likewise, the heterogeneously grouped students scored higher than the students identified as low ability.

These data indicate to the researchers that the targeted students are more capable of doing inductive and deductive reasoning, reasoning which requires them to decide which conclusions can be reasoned from given facts. The students had more difficulty with the sections of the test that required them to make judgments on the credibility of given statements and to decide what the hidden assumptions are in given statements.

Table 1

Teachers' Views of Thinking Strategies They Use in Their Classes

Statement	Daily	Often	Sometimes	Never	No Response
ask students to "think out loud"	20	29	20	9	2
allow students to say "I can't"	2	4	14	58	1
use learning logs/journals	11	27	32	10	
share how I tackle a problem	18	48	14	0	
share objectives of lesson	35	40	5	0	
use graphic organizers	7	28	33	11	1
require writing with reading assignment	19	39	18	4	
"think out loud" in class	12	42	24	1	1
hold open class discussion	24	32	22	2	
role is to facilitate learning	51	21	7	0	1
teach how to read & understand text	29	33	16	0	
teach thinking skills in content	38	31	9	2	
	Strongly Agree	Agree	Unsure	Disagree	Strongly Disagree
adequately prepared to teach thinking skills	25	35	18	2	0

n = 80

Also during the first week of the school year, the faculties of the targeted schools were surveyed (Appendix B) on how they incorporate critical thinking skills into their pedagogy. Surprisingly, of the 80 teachers who responded, 86% indicated in statement 12 (Table 1) that they specifically teach thinking skills in their course content often or on a daily basis. However, in statement 13, only 75% of those same teachers agree or strongly agree that they are adequately prepared to teach those skills. When the surveyed teachers were specifically asked to furnish an example of how they teach or incorporate critical thinking skills in their course content, only 20% supplied an example. Of the examples

provided, only one-half exemplified critical thinking as defined by Richard Paul (cited in chapter 1). The limited number of examples provided, compared with the large number of teachers who responded that they specifically teach thinking skills, implies to the researchers that the teachers may not have a clear understanding of what critical thinking skills are or how to teach them. Overall, a majority of the teachers surveyed indicated that they use one or more critical thinking techniques at least some of the time.

Table 2

Students' Views Regarding Teachers' Use of Thinking Skills/Strategies in Their Classes

Statement	Daily	Often	Sometimes	Never	No Response
teachers ask students to "think out loud"	4	18	66	19	1
teachers allow students to say "I can't"	1	2	31	74	
teachers have students use learning logs	5	31	62	10	
teachers share how they tackle a problem	5	43	55	5	
teachers share objectives of lessons	22	49	33	3	1
teachers use graphic organizers	13	41	51	3	
teachers ask students to write when reading	15	53	35	0	5
teachers "think out loud" in class	14	43	45	6	
teachers hold open class discussions	31	41	33	3	
teachers are responsible for student learning	28	27	47	6	
teachers teach how to read & understand text	21	44	37	6	
teachers teach thinking skills in class	19	48	38	3	

n = 108

In a parallel survey (Appendix C), the targeted students were asked to indicate how often they observed their teachers utilizing critical thinking techniques in the classroom. Of the 108 students surveyed, most students affirmed the teachers' perception that critical thinking skills are being taught and practiced at least sometimes in most classrooms (Table 2). Remarkably, there was only a .5% to 12% difference between the students' and teachers' responses to parallel statements. The similarity between the results of the two surveys indicates to the researchers that both teachers and students believe that critical thinking skills are being taught on a relatively consistent basis. The researchers, however, question

this perception because of the lack of critical thinking examples provided by the surveyed teachers combined with their own observations of the students' inability to distinguish between lower and higher level thinking skills.

Table 3

Students' Views of Their Own Use of Thinking Skills and Strategies

Statement	Always	Sometimes	Never
I "talk to myself" when not sure of problem	41	62	5
I guess when not sure on multiple choice tests	22	74	12
I get suggestions from group on difficult problems	75	31	2
when frustrated/confused, I ask why	26	55	27
I use graphic organizers when studying	7	75	26
I find class discussions helpful	75	33	0
when I don't know, I immediately ask someone else	20	78	10
teacher must make sure I learn	26	67	15
I see connections from one class to another	20	82	6
on multiple choice tests I eliminate answers before guessing	73	27	8
I find small group discussions helpful	62	45	1
I use only notes or textbook when studying	47	54	7
I see connections from start to end of course	37	68	3
writing out ideas helps clarify them	29	67	12
teacher is responsible for my learning	19	75	14

n = 108

The targeted students were also surveyed on their perceptions of how often they use critical thinking skills and strategies (Appendix D). The survey revealed that almost all of the students feel that they benefit from both small group and whole class discussions at some time (Table 3). In addition, these students indicated that they are at least sometimes able to make connections from one class to another and from the beginning of a course to its end 94% and 97% of the time respectively. Graphic organizers are sometimes used when studying by 76% of the students, while 89% stated that writing out their ideas provides some help in clarifying them. Nonetheless, 86% of the surveyed students expect teachers to assume some responsibility for individual student learning. All in all, the researchers noted

that the vast majority of surveyed students believe that they always, or at least sometimes, use strategies (self or teacher initiated) that enhance their ability to think.

Table 4

Teachers' Views of Their Students' Use of Thinking Skills and Strategies

Statement	Often	Sometimes	Rarely	Never	No Response
students give up quickly	36	38	4	2	
students blurt out answers without thinking	24	41	11	1	
students listen to one another with empathy	25	38	15	0	
students consider alternative points of view	20	43	15	0	
students reflect on/evaluate their thinking	6	32	39	0	1
students check for accuracy & precision	4	41	31	2	
students ask well thought out questions	7	60	11	0	
students draw on past knowledge	12	57	8	1	
students apply knowledge to real-life	6	53	13	1	5
students' language is vague/imprecise	19	51	8	0	
students are willing to take risks	8	51	17	1	1
students use cooperative group time well	24	46	7	1	

n = 78

In a second survey (Appendix E), the teachers from the targeted schools were asked to indicate how often they observed their students applying strategies essential to critical thinking. Only 8% of the teachers surveyed stated that their students worked persistently in class (Table 4). At the same time, 86% viewed their students as asking well thought out questions, while 83% indicated that students many times will blurt out answers without thinking. Approximately 82% of these teachers stated that students can transfer past knowledge to current and real-life situations. The teachers are almost equally divided in their view of whether or not students reflect on and evaluate their own thinking. On the whole, the teachers seem to assume that their students think critically because they use several critical thinking skills at various times.

Table 5

Parents' Views Regarding Their Child's Study Area and Homework

Statement	Always	Often	Sometimes	Never
child studies in quiet area	19	18	39	13
TV/stereo/radio in study area	41	24	20	4
TV/stereo/radio is on while studying	20	30	24	15
child asks for help with homework	2	9	57	21
I feel confident when helping with homewor	15	27	33	12
I ask questions about homework	18	25	37	9
I ask that homework be explained to me	10	22	45	12
I ask to see completed homework	9	11	33	36
telephone in study area	34	17	24	14
child makes/accepts calls when studying	17	16	47	9

n = 89

In the final survey (Appendix F), parents were asked about their views concerning the area in their home where their child does homework. Close to 42% of those surveyed stated that their child frequently studies in a quiet area (Table 5). However, 90% of those parents indicated that there is a TV, stereo, radio, or telephone located in the study area and over 86% disclosed that at least one of those potential distractions is being used. Parents were also asked about what role, if any, they assume in helping their child with homework. Almost 50% of the parents frequently question their child about homework, while only 36% regularly ask their child to explain to them what is being done for homework. Hence, the results of this survey indicate that the majority of students study in an area where they can be frequently distracted and that many seldom use their parents as a resource when doing homework.

As a result, the researchers, in comparing the data collected with Richard Paul's definition of critical thinking, believe that the teachers and students surveyed assume that any thinking is critical thinking. Their responses tend to affirm what the research indicates is a misunderstanding of what critical thinking entails.

As Barbara Presseisen (1991) states, "Without a common understanding of what we mean by thinking, we cannot even begin to address the extensive problems associated with the development of students' higher cognitive performances" (p. 62).

Probable Causes

"Each of us is involved in episodes of critical thinking every day, whether we are aware of it or not. We make judgments, form decisions, and take actions based on the assumptions we hold about what is true" (Brookfield, 1991). Since the beginning of recorded history, men and women have striven to think critically. Early philosophers, such as Socrates, Plato, and Aristotle, used an inductive approach to arrive at what they determined to be universal truths. The Socratic method of questioning is still used today to help develop and foster critical thinking skills in students. This method requires students to engage in dialogue to investigate problems and formulate and logically test hypotheses (Fillinger, 1990).

Continuing in the tradition established by these early philosophers, our American forefathers also indicated an understanding of the importance of an educated populace. Thomas Jefferson writes (as cited in Beyer, 1995, p.28) "A democracy cannot survive unthinking citizens." To be a thinking citizen in a democracy and a rapidly changing world requires that people be able to make informed judgments about personal, social, political, and economic issues (Beyer, 1995). In fact, the need for having an educated society is the basis on which the free public school system in the United States was founded.

Why, then, has the teaching of thinking become such a popular endeavor today? It is important to remember that concern for developing students' thinking has been, and still is, one of the most persistent and ambitious aspirations of education since the time of Plato.

Piaget affirmed that the primary goals of education are to develop minds that are creative, inventive, and critical; minds that can verify information and not simply accept everything as presented (Seiger-Ehrenberg, 1978).

Finally, as many may recall, during the late 60's and early 70's, there was a paradigm shift in curriculum from rote instruction to emphasis on concept development. However, this reform movement was short-lived and quickly replaced by the "back to basics" movement of the 70's. Interestingly, the "back to basics" approach was begun in response to documented difficulties many students were encountering with the basic skills involved in reading, writing, and arithmetic. In fact, with this change in "back to basics", the National Assessment of Educational Progress, along with other agencies, discovered that although reading, writing, and arithmetic skills improved through concentration on basic skills, higher-order thinking still left much to be desired. In fact, the ability of students to use higher-order thinking skills showed a marked decline from those of students a decade earlier (Swartz & Perkins, 1990).

Today the push for educators to teach critical thinking skills has returned to the forefront, ... but, why now? Several national testing programs and recent reports on the quality of primary and secondary education in the United States indicate that students are performing far below standards expected in mathematical problem-solving, critical and creative writing, and interpretive reading (Swartz & Perkins, 1990). As indicated previously in Chapter 1, the CEO's of major corporations agree by stating "students coming into today's workplace are dramatically lacking in higher-level thinking skills, the ability to diagnose and solve problems, and the fundamentals of math, reading, and writing" (Nidds & McGerald, 1995, pp. 27-28). Implied is the fact that this lack of higher-order thinking skills

will have a negative effect on the United States' competitive position in the high-tech world of the future. Therefore, it is imperative that serious attention be given to the intellectual development of students.

Interestingly, the literature suggests several underlying causes for the lack of critical thinking skills in today's high school students. In one recent study, Yildirim (1994) found that most of the teachers he surveyed realize that one of their major responsibilities as educators is to foster critical thinking in their students. However, over 50% of the teachers polled indicated they felt only adequately prepared to teach critical thinking skills, while another 14% felt inadequately prepared to do so (Supon, 1998). Further, many teachers are resistant to the idea of changing their teaching style from lecture driven to discussion and dialogue. Teaching through discussion and dialogue is hard work. It necessitates teachers spending more time creating "thought-full" lessons that will involve students in critical thinking. Moreover, additional time is needed to implement these lessons, thereby making it difficult to fit a critical thinking lesson into a 50-minute time constraint. Finally, employing critical thinking lessons on a regular basis may prevent teachers from covering the designated curriculum. Indeed, the pressure to cover course content forces many teachers to push critical thinking to the back burner (Benderson, 1990).

At the same time teachers are constantly being pressured to raise students' standardized test scores, a pressure that also increases the stress on them to cover more content. Not surprisingly, these pressures combine to produce classrooms that are teacher-centered rather than student-centered. McLean-Briggs responds to these suggested causes for the lack of critical thinking skills in today's high school students: "Schools should not be organized for teachers to teach but for children to learn" (as cited in Costa & Marzano, 1991).

Finally, national surveys have indicated that the way most schools are organized cripple efforts to teach critical and creative thinking. Logistics, such as length of instructional time, homogeneous versus heterogeneous grouping of students, assemblies, and educational mandates from federal, state, and local governing agencies, leave little time to pursue quality instruction. Furthermore, school work traditionally has focused on individual thinking rather than collaborative decision-making. Teachers have rarely encouraged students to question each other, the teacher, or the information printed in textbooks. Higher order questions are seldom raised nor are students challenged to justify their thought processes. Passive learning has been emphasized in the classroom, a learning that cannot prepare students for their participation in the active social environment in which they live (Adams & Hamm, 1990; Newmann, 1988).

For their part, many teachers are unclear about how to use appropriate strategies to teach critical thinking. Instead of modeling how to perform a specific thinking skill, teachers provide students with situations in which they must apply the skill, and in doing so, assume the students will acquire the necessary skill and be able to transfer its use to other situations. Unfortunately, such teaching tends to frustrate students and to reinforce inaccurate applications of the skill (Beyer, 1984).

In short, through their review of the literature, the researchers from sites A and B believe that the causes listed above all stem from the inadequate training of teachers. Many teachers do not understand what skills are necessary to enable students to think critically nor do they know how these skills should be taught.

Nonetheless, students must also assume some responsibility for their acquisition of critical thinking skills. As Halpern states, "One of the major differences between good and poor thinkers, and correspondingly between good and poor students, is their attitude." Many students do not want to put forth the time and energy needed to develop critical

thinking skills. Several experience difficulty participating in class discussions on assigned reading because they have failed to read the assignment or they do not understand what they have read. Many will frequently answer with the first idea that comes to mind. If a certain task appears difficult, some students give up without even trying or they make a few feeble attempts before declaring "I can't do it!" Even when writing or taking an exam, too many students begin to write before they begin to think (Halpern, 1997; Sutton, 1997).

Not surprisingly, complaints consistently voiced by teachers reiterate the concerns teachers have about students' attitudes toward learning. Paul, Binker, Martin, and Adamson (1995) indicate these complaints include:

> "Most students aren't motivated; they don't want to study or work. They look for chances to goof off, clown around, disrupt class. They'd rather talk about music, clothes, cars, ..."
>
> "Students forget what they've learned. We have to keep going over the same points, reminding them of what they've learned, rather than building on past learning. Each class begins at square one."
>
> "Most students are obsessed with grades and don't care about learning."
>
> "They're impatient. They want clear simple answers and they want them fast."
>
> "They make the same mistakes over and over again. They don't learn to correct their own mistakes."
>
> "They don't use what they've learned."
>
> "They need to be told every little thing. They don't even try to figure things out. They want us to do all of their thinking for them."
>
> "When I ask if there are questions they don't have any; but they haven't understood."
>
> "When assigned position papers, many students just write facts. The rest simply state and repeat their feelings."

"They hate to read. (It's boring.)"

"They hate to write. (It's too hard.)"

"Instead of explaining or developing their ideas, they just repeat themselves."

"They can't seem to stay on topic for long without going off on tangents" (pp. 2-3). Even the report "Reaching Standards: A Progress Report on Mathematics" confirms that students average about three hours more time watching television than they spend studying math, reading, or writing (Lewis, 1995).

Clearly, students learn many things in school beyond the facts they are taught. Their experiences incorporate not just what they've learned but how they've learned. Life is a struggle whether we like it or not, and how students deal with their struggles in school will help prepare them to deal with the struggles they'll face in life. "The opportunity begins when the struggle begins" (Sutton, 1997).

CHAPTER 3

THE SOLUTION STRATEGY

Literature Review

A current trend in education stresses that students preparing for the 21st century must acquire a variety of critical thinking skills. As Hannel and Hannel (1998) have proposed:

> In the task of helping students become critical thinkers, two impediments stand in the way. The first is a widespread misdiagnosis about why students fail to become critical thinkers in the first place, and the second is the lack of a practical instructional strategy for teaching critical thinking skills in the classroom. Both of these problems can be remedied. (p. 87)

One possible remedy, as reported in *Breaking Ranks*, a study commissioned by the National Association of Secondary School Principals, is to have high school educators teach students how to develop the ability to draw inferences, make informed decisions, apply logical reasoning, and solve real world problems. A broad knowledge of basic facts serves as a necessary foundation for critical thinking, but the emphasis of high school teaching should be the acquisition and application of those facts through thinking and problem solving. Further, in this technological age where facts can be acquired at the touch of a button, students must learn to identify what information is needed to solve the problem at hand, and how and where to obtain that information (May 1998 NASSP Bulletin, p. 86).

Clearly, research has indicated numerous approaches for helping to remedy the lack of critical thinking in high school students. As Ian Wright (1995) indicates, there are three documented models for teaching critical thinking: a separate course/unit specifically on critical

thinking skills, infusion of critical thinking skills into the already existing curriculum, and a strategy that combines the first two models. Each of these models has both advantages and disadvantages.

Wright explains that in using the separate course/unit model, teachers can utilize ready-made, easily obtainable materials created by experts in the field. These materials are accompanied by guides for the teacher and instructions for students that are clear and understandable. This model maximizes learning for both teachers and students. A further advantage is that this approach fosters a more critical attitude since it is designed to encourage critical thinking rather than just assisting in the learning of particular course content. On the other hand, in using this model, the knowledge of specific critical thinking skills that is gained may not be transferred throughout the rest of the curriculum. Furthermore, some would protest that incorporating a separate course on thinking skills would require additional time in an already crowded school day (p. 139).

Another model for teaching critical thinking skills is commonly called infusion. In this method the skills are taught using the already existing subject matter. Wright suggests that in using this model students can learn critical thinking skills by directly applying them to the particular course content being studied, thereby eliminating the need for an extra time slot in the school day (p. 140). However, critics of this model believe that for it to be well implemented, all teachers must be competent in their understanding of what critical thinking skills are and how best to teach them. Also, teaching critical thinking skills through infusion may lack the appropriate sequencing and cohesiveness needed for mastery (Wright, 1995, p. 140).

Wright seems to favor a combined approach to teaching critical thinking, one that attempts to reap the benefits of both of the other models. These benefits include:

- transfer would be (theoretically) guaranteed
- separate units on critical thinking skills could be taught by experts in that particular area

- students would be exposed to a wide variety of critical thinking standards across the curriculum from K - 12
- the programs designed by the experts could be adapted to fit local conditions.

Wright points out no specific disadvantages; however, the researchers from the targeted schools believe time is still a crucial factor. Also, additional personnel would be needed to provide teachers the necessary expertise or training (p. 140).

But where does one start? One strong suggestion indicated throughout the review of the literature is that to improve critical thinking skills in students requires the collaborative commitment of administrators, teachers, students, and parents. All must work together to create an atmosphere where critical thinking skills are fostered and valued (Collins 1989, Paul 1995, Sanders 1998, Sutton 1997). Administrators need to increase their own understanding of the strategies needed to teach critical thinking skills, provide ongoing opportunities for teacher inservice on how to apply those strategies in the classroom, support the teachers as they attempt to implement the strategies learned, and hold students accountable for increasing their thinking abilities. Administrators must also establish a climate that sets high expectations for both its teachers and students. They should be highly visible and show genuine interest in what teachers and students are achieving. Finally, they should implement programs that send the message "everyone is expected to succeed." Administrators who demonstrate such support and leadership inspire teachers to teach, students to learn, and parents to become active partners in their child's education (Collins 1989, Johnson, 1997).

Further, teachers need to promote critical thinking through modeling and structured activities that foster and encourage student thinking. Of the numerous strategies that can be used to teach critical thinking, the most successful seem to include: cooperative learning activities, higher-order, open-ended questioning, sufficient wait-time, and abundant opportunities for transfer (Potts, 1994). Activities can include: graphing, summarizing, interpreting, classifying, comparing and contrasting, researching, evaluating, identifying fact or opinion, generalizing,

drawing parallels, self-correcting, and hypothesizing (Tener, 1995, p. 101). Teachers must also create a risk-free environment in which the values of critical thinking are recognized and encouraged. According to Paul, Binker, Martin, & Adamson (1995), the role of the teacher in a classroom where critical thinking is valued could be summarized as follows:

- help break big questions or tasks into smaller, more manageable parts
- create meaningful contexts in which learning is valued by the students
- help students clarify their thoughts by rephrasing or asking questions
- pose thought-provoking questions
- help keep the discussion focused
- encourage students to explain things to each other
- help students find what they need to know by suggesting and showing students how to use resources
- ensure that students do justice to each view, that no views are cut off, ignored, or unfairly dismissed (p. 23).

For their part, students must develop a more positive attitude toward learning and be willing to adapt to different instructional methods. They must persevere when the thinking gets tough. According to Perkins (as cited in Goode, 1995, p.16):

> When Americans confront a difficult intellectual challenge, they commonly say, "Well, it's just too hard. You either get it or you don't." In Japan, failure to overcome a challenging situation is not attributed to a lack of intellectual ability but a lack of effort. The way to deal with a difficult problem or a puzzling concept is to persevere systematically until you have mastered it.

Clearly, to become effective learners, students must be constantly curious and questioning. They should seek out challenges and enjoy figuring things out. They must become independent learners who are resourceful, flexible, and stay with a task to its completion. Critical thinkers need to be risk-takers who are willing to fail because they realize that success can be gained through failed

attempts. They recognize that failure is a necessary part of problem-solving, not a personal reflection of their own shortcomings. In order to acquire these skills, students must learn to be well organized and systematic in the way they approach different parts of a task. They must think before they act and be mindful of their own thinking process (Casey & Tucker, 1994).

But what visible signs should students exhibit as they become more actively engaged in critical thinking? Costa and Lowery (1989) have compiled a list of overt indicators that synthesizes many of the ideas indicated by several researchers who have studied and analyzed efficient, productive, and creative thinkers. These behaviors include but are not limited to:

- persevering when the solution to a problem is not immediately apparent
- making fewer erasures on their papers
- gathering much information before they begin a task
- taking time to reflect on an answer before giving it
- making sure they understand directions before beginning a task
- listening to alternative points of view with understanding and empathy
- planning a strategy for solving a problem
- paraphrasing another's point of view or rationale
- providing several methods to solve the same problem and evaluating the merits of each of the methods used
- communicating using clear and precise language, both orally and in writing, their thought processes
- checking for accuracy and precision
- asking higher-order questions
- drawing on previous knowledge and experience to support, explain, or solve a new challenge
- transferring school-learned knowledge to real-life situations and to content areas beyond that in which it was taught

- taking risks without fear of failure
- producing creative, novel, resourceful, imaginative ideas and products (pp. 90-100).

However, the true test of a student's competence is not the mere possession of a skill, but the application of that skill in a real situation.

Finally, parents need to be supportive and encouraging as students struggle to develop their critical thinking skills. Even at the secondary level, parental involvement and support is important for students' success in school. As Jeremy Finn (1998) states,

> Researchers have identified three types of parental engagement at home that are consistently associated with school performance:
>
> - actively organizing and monitoring the child's time;
> - helping with homework; and
> - discussing school matters with the child (p. 20).

Parents, especially at the secondary school level, need to assist their children in prioritizing their responsibilities concerning academic success. Moreover, even though parents may not be familiar with specific course content, they should question and examine completed homework. This very act shows the importance parents attach to their child's school work. Parents must also be helped to realize that struggle is normal and that it takes time to learn new concepts. They should encourage their children to take responsibility for their own learning and any struggles that ensue. They should also resist the temptation to blame any difficulty in learning on a lack of innate ability (Halpern 1997, Sutton 1997, Sanders 1998).

Project Objectives and Processes

As a result of increased instructional emphasis on critical thinking skills, during the period of September 1998 to February 1999, the high school students from the targeted classes will develop or increase their ability to use critical thinking skills in mathematics and social studies, as measured by the Cornell Critical Thinking Test - Level X, teacher-constructed tests, projects, and assignments, and reviews of student portfolios.

In order to accomplish the project objective, the following processes are necessary:

1. Materials and language that foster critical thinking in mathematics and social studies will be developed.
2. A series of learning activities that stimulate critical thinking will be developed for both math and social studies.
3. Curricular units reflecting these decisions will be constructed.

Project Action Plan

After gathering information pertaining to critical thinking, the researchers at both sites decided to incorporate teaching strategies and activities intended to develop and improve the critical thinking skills of their students. Since language is central to the development of an individual's cognition, the researchers will deliberately use "thought-full" language in their everyday classroom. This intentional focus on language should challenge students to think on a day-to-day basis. At the beginning of September the researchers will provide the students with a glossary of vocabulary used by critical thinkers and take the time to explain each term because students must understand the language in order to facilitate their cognitive growth.

Reading is an essential life skill and an important component of any critical thinking process. Considering that many students experience difficulty comprehending what they read, the researchers will model reading for comprehension by having students read aloud in class and then interpret/paraphrase what has been read. Consistently inviting students to restate, translate, and paraphrase what they have read should cause them to become better listeners to their own thinking.

Since students often blurt out the first answer that comes to mind, the researchers will frequently use a variety of questioning techniques and open-ended questions combined with appropriate wait time. This should encourage students to take time to reflect on an answer before responding, while decreasing their impulsivity and increasing the number of correct responses.

The researchers at each site will implement cooperative learning early in September by structuring the targeted classes into groups of three or four. Activities will be scheduled on a weekly basis and are intended to broaden the students' perspective, allowing them to become more flexible in their thinking. Students will be asked to consider alternate points of view, assimilate and internalize several sources of information simultaneously, solve the same problem more than one way, and resolve conflicts through compromise. Also, a conscious effort will be made on the part of the researchers to include lessons incorporating multiple intelligences. These lessons should help students become more comfortable with the course content while, it is hoped, increasing their willingness to think.

High school students are more likely to be actively involved in the problem solving process when the problems presented deal with situations familiar to them. Every attempt will be made to incorporate significant information from the students' lives into the problems discussed in class. This should increase students' interest while allowing them to draw on past knowledge and experiences. In addition, it should expand their ability to transfer school-learned knowledge to real-life situations.

Finally, students in the targeted classes will be asked to write reflective journal entries. Some of these entries will be in response to given prompts, some in response to problem-solving situations, and some determined by the student's personal choice. Keeping journals should encourage students to synthesize their thoughts and actions, allow them to locate errors in their thinking process and make changes as necessary, and cohesively translate their ideas into written words. This strategy should prompt students to think about their thinking, a necessary characteristic of a critical thinker.

Methods of Assessment

In order to assess the effects of the intervention, the Cornell Critical Thinking Test - Level X will be re-administered. In addition, teacher-made tests, projects, and activities covering the specific thinking skills will be developed.

CHAPTER 4

PROJECT RESULTS

Historical Description of the Intervention

The objective of this project was to improve the students' use of critical thinking skills in secondary math and social studies classes. The implementation of cooperative learning structures, use of clear and precise language, critical reading and analysis, justification of thought processes, Socratic questioning, reflective writing, and numerous learning activities intended to stimulate critical thinking were selected to effect the desired changes.

The researchers began by administering the Cornell Critical Thinking Test - Level X as a pretest the first week of the school year (Appendix A). The test was given over a three-day period to insure sufficient time for students to read and think carefully. There were four sections to the test: induction, credibility, deduction, and assumption. The induction section was administered on the first day, the credibility section on the second day, and both the deduction and assumption sections on the third day. After the test was administered, the researchers realized that the test could have been administered in a single 50-minute class period.

The research sites are designated as Classrooms A, B, and C. Researcher 1 applied the interventions in Classroom A to tenth grade students, identified as having low math ability, who are participating in the second year of a two-year algebra program. Researcher 2 applied the interventions in Classroom B to ninth and tenth grade students in an honors geometry program. Researcher 3 applied the interventions in Classroom C to eleventh and twelfth grade heterogeneously-grouped students in American law classes.

Cooperative learning groups were begun in all three classes during the second week of the school year. Each quarter, the researchers used a different method to establish the cooperative learning groups. During first quarter, students in Classroom A were allowed to choose a partner and then two sets of partners were paired by the researcher to form base groups. In Classroom B, students were allowed to choose their own base groups, while in Classroom C, due to absenteeism, students were allowed to form new groups for each project. During second quarter, the students in Classroom A were partnered by the researcher and then each pair of partners was allowed to choose another pair with whom to work. In Classroom B, the students were allowed to choose a partner and then two sets of partners were paired by the researcher. In Classroom C, the students were allowed to choose their own base group consisting of at least six students each. Students who were not immediately chosen were assigned to a base group by the researcher. This larger base group was necessitated by the continuing absentee problem. Cooperative learning skills were established and modeled, and appropriate expectations were set for each classroom. These base groups were used for studying, clarifying concepts and ideas, checking homework, working on both short and long-term projects, researching, and practicing higher-order thinking skills through problem-solving activities.

Once cooperative groups were established, the researchers began to focus on teaching critical thinking skills. Students in each classroom were given a glossary of "thought-full" vocabulary (Appendix G). Time was spent explaining the meaning and use of each word, as well as the necessity of using clear and precise language when speaking and writing. Students were expected to understand and correctly use this vocabulary in their reflective writing.

Throughout the five-month intervention period, all the classrooms were engaged in critical thinking activities that fostered analysis, justification of thought processes, Socratic questioning, reflective writing, and higher-order thinking. The selected critical thinking skills were taught

through the specific course content rather than taught as a separate unit. Due to restrictions of a daily class schedule, the planned number of interventions was altered. Critical reading was not stressed.

Since the Cornell Critical Thinking Test - Level X focused on four specific areas of critical thinking, the researchers developed activities that concentrated on those areas. These activities were employed whenever appropriate to the course content. To encourage and foster inductive reasoning, the students in Classroom A were given various number problems in which they were asked to find a pattern or generalization about the numbers in each problem. The students in Classroom B worked on discovery lessons that allowed them to reason from particular observed facts to a general statement. The students in Classroom C researched specific issues in order to develop a justifiable conclusion (Appendix H).

To motivate students to justify the credibility of given situations, all three researchers presented students with problems in which they had to judge the credibility of the answer reached and explain their reasoning in clear and precise language (Appendix I). The researchers also used Socratic questioning to guide students in analyzing the validity of their solutions.

Since the results of the Cornell Critical Thinking pretest indicated that the deductive reasoning skills of the targeted students were the most highly developed, the goal of the researchers was to enhance and expand those skills. The students in Classroom A solved equations and inequalities and justified each step of the process, while the students in Classroom B proved theorems using the two-column deductive proof format. They also had to reason logically to create their own geometry and to reorganize the steps in a jumbled proof and justify each step. The students in Classroom C were asked to draw and test conclusions based on the use of good syllogisms (Appendix J).

Finally, to help students further develop their ability to recognize the validity of assumptions being made, the students in Classroom A were given a problem of the week that they were required to analyze, restate in their own words, solve, and justify their solution to the problem. These were randomly selected problems chosen to reinforce previously acquired skills. The students in Classroom B were asked to analyze numerous problems in order to decide what assumptions they could or could not make from the information and/or diagrams given. In Classroom C, the students were asked to read several different perspectives of the same event and then make assumptions, based on what they read, about what actually happened (Appendix K). Following several of the activities, all of the targeted students were required to reflect in writing to clarify their understanding.

Finally, the Cornell Critical Thinking Test - Level X was re-administered as a posttest by Researcher 3 during the second week of January and by Researchers 1 and 2 during the last week of February. Researcher 3 administered the test earlier due to the fact that the targeted students of Classroom C were involved in a semester course which ended two weeks earlier than scheduled.

Presentation and Analysis of Results

In order to assess the effects of cooperative learning and higher-order thinking activities on the students' ability to think critically, the Cornell Critical Thinking Test - Level X was administered to the targeted students at the end of the intervention period. The results of the pretest and posttest are presented in Figures 2 and 3, respectively.

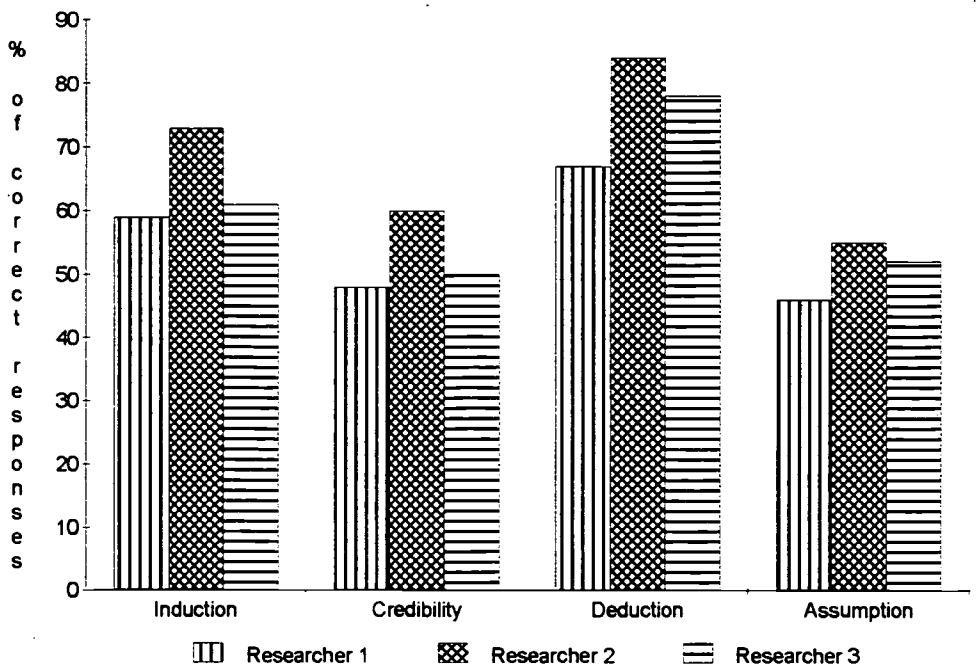

Figure 2. Results of the Cornell Critical Thinking Test - Level X for the targeted classes administered as the pretest the last week of August 1998.

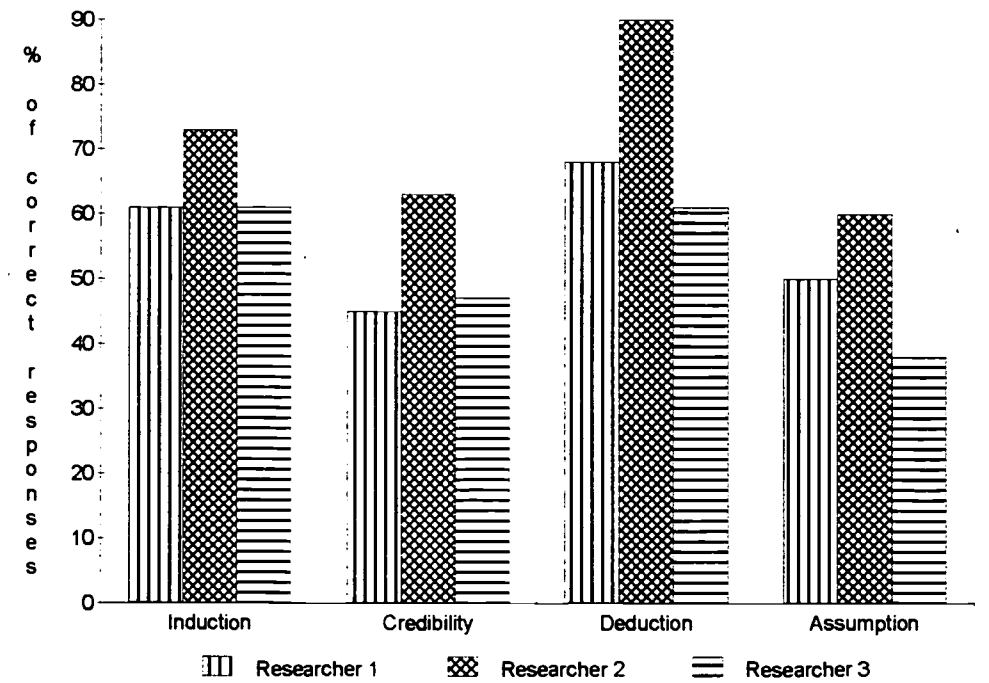

Figure 3. Results of the Cornell Critical Thinking Test - Level X for the targeted classes administered as the posttest the last week of February 1999.

The intervention appears to have had little effect on the targeted critical thinking skills. As indicated in Figure 3, the targeted students correctly responded to questions that required inductive reasoning with a combined accuracy rate of 65%, an increase of 1% from the pretest. However, the students responded correctly to questions requiring deductive reasoning with a combined accuracy rate of 73%, down 2% from the pretest. In section two of the test, which required students to judge the credibility of an assertion, the students' combined accuracy rate was 52%, down 1% from the pretest. In part four, which required students to identify reasonable assumptions, their combined accuracy rate was 49%, down 2% from the pretest. Overall, there was a slight decrease in the percent of correct responses given on the posttest.

However, despite this slight decrease, on the average, over 30% of the targeted students improved their score in each of the targeted areas (see Figure 4).

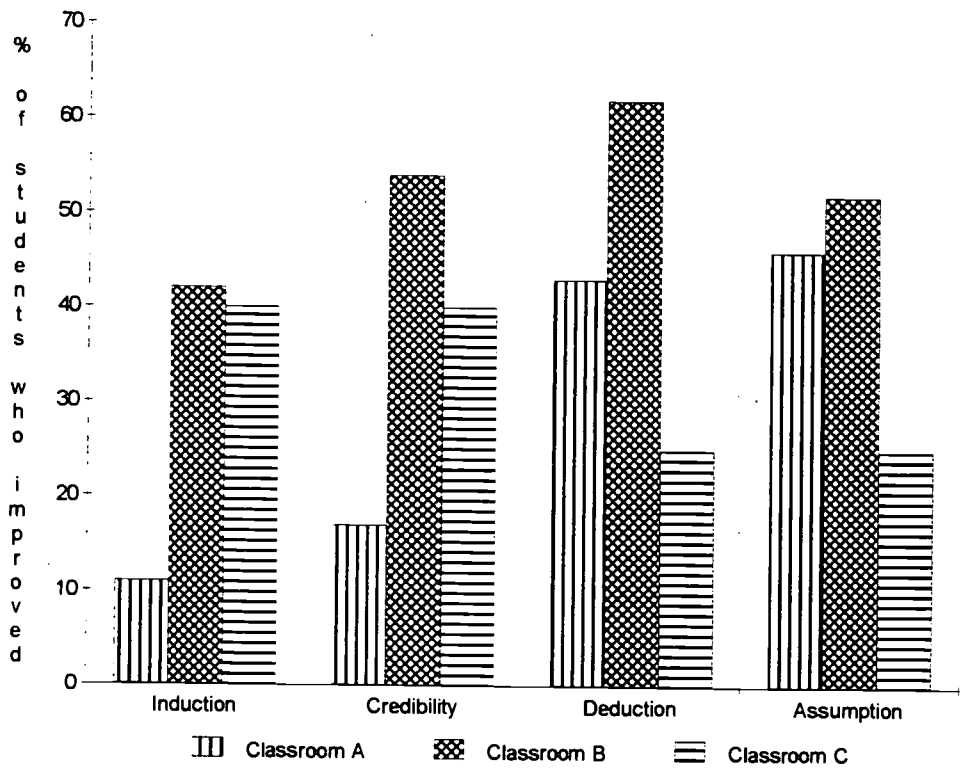

Figure 4. Percent of students who improved their score on the Cornell Critical Thinking Test - Level X from August 1998 to February 1999.

The students in Classroom A, as indicated in Figure 4, showed the greatest improvement (46%) in the assumption recognition section of the Cornell Test. Researcher 1 thinks that this can be attributed to a four-week unit on problem solving where several specific strategies were practiced. This unit was followed by problems of the week that required the students to identify which information was relevant or irrelevant in solving the problem. Another contributing factor to the students' improved scores in this area could be the fact that students had to give a written justification for their solution. Since this was done on a weekly basis, Researcher 1 did notice an improvement in the students' written responses throughout the intervention period.

The students in Classroom B, as indicated in Figure 4, showed the greatest improvement (62%) in the deductive reasoning section of the Cornell Test. Since geometry, by its very nature, emphasizes deductive reasoning, Researcher 2 attributes the students' improved scores in this area to the strategies involved in teaching the specific course content. Detailed proofs that require logical reasoning and justification for each step, as well as, analyzing diagrams for pertinent information are possible explanations for this gain. Since these types of activities are done on an almost daily basis in geometry, Researcher 2 did notice improvement in the students' ability to critically break down diagrams into their essential elements and logically reason from given statements to the statement to be proved.

The students in Classroom C, as indicated in Figure 4, showed the greatest improvement (40%) in both the induction and credibility sections of the Cornell Test. Researcher 3 credits this improvement in scores to an in-depth three-week research of critical issues concerning the foundation of the United States system of government. The students were expected to evaluate primary source material related to American history and form verifiable opinions. Since this project was student-centered with individuals choosing their primary sources, Researcher 3 recognized that, over time, students were better able to eliminate biased information in order to reach a fact-based conclusion.

Conclusions and Recommendations

Based on the presentation and analysis of the data on critical thinking skills, it may appear that the students did not show a marked improvement in their ability to think critically. The lower number of correct responses on the Cornell Critical Thinking posttest may be attributed to the fact that:

- some students may not have taken the test seriously because they did not receive a grade on it
- the short span of time between the administration of the pretest and posttest could have resulted in some students not reading as thoroughly the second time
- the shortness of the intervention period may not have allowed adequate time for some students to internalize and transfer the skills taught.

However, the researchers did notice improvement in specific behaviors that were not tested on the Cornell Critical Thinking Test. The students, at times, exhibited the following behaviors indicative of critical thinkers:

- increased perseverance when presented with challenging problems
- increased time spent reading and clarifying directions before beginning a task
- increased willingness to listen to alternative points of view
- improved oral and written communication skills
- increased risk-taking
- improved quality of work
- improved willingness to ask questions, some of which were higher-level.

Overall, the researchers noticed a marked improvement in students' attitudes toward critical thinking. In a school-wide evaluation, a vast majority of the targeted students in Classrooms A and B indicated that they felt challenged to think critically. In Classroom C, the targeted students competed in a regional competition on a mock congressional hearing and were awarded second place. These students were overwhelmed by the level of their accomplishment.

In general, all three researchers experienced some satisfaction in witnessing the improvement, however slight, in their students' attitudes toward critical thinking. The researchers plan on continuing to integrate the teaching of critical thinking skills into their regular curriculum. They believe that as they improve their own ability to teach critical thinking, their students' ability to think critically will improve also.

However, the researchers concluded that the earlier critical thinking skills are introduced in a child's education, the easier they will be to internalize and transfer. To begin to teach critical thinking skills at the secondary level can be met with much resistance; regardless of when they are begun, however, they are still essential to the students' development. All teachers must take the time necessary to teach and re-enforce these important skills. Likewise, the researchers recognize that critical thinking, as well as the teaching of essential critical thinking skills, is hard work and requires much time, but is well worth the effort. Teachers need to continue to develop lessons that incorporate critical thinking strategies and challenge students on a daily basis to apply those strategies. In order to accomplish such teaching, the teachers themselves must become critical thinkers and recognize that this "becoming" is a lengthy process. We researchers also came to the realization that it would have been an excellent idea to videotape our own group process of researching, collaborating, thinking "out loud," sharing different points of view, and coming to consensus as we determined the most clear and concise language for use in our own action research paper. This video could then have been played for our students to show them that cooperative group skills and critical thinking skills are a part of life-long learning. In our collaborating on this paper, we ourselves have both internalized and applied critical thinking skills to analyze and attempt to solve a complex problem facing many teachers today. In doing so, we have taken the first step in teaching these "critical" skills to our students; we have modeled them. As teachers entering this new millennium, we are ready to meet today's educational needs while at the same time preserving the ancient proverbial wisdom: "Give me a fish and I will be fed today. Teach me how to fish and I will be fed forever."

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APPENDICES

Appendix A

Cornell Critical Thinking Test Level X

A copy of the Cornell Critical Thinking Test Level X can be purchased from

Critical Thinking Press & Software
P. O. Box 448
Pacific Grove, CA 93950-0448
Phone: 800 - 458 - 4849
Fax: 408 - 393 - 3277
ISBN 0 - 89455 - 286 - 4

Appendix B

Faculty Survey

DIRECTIONS: Please respond to each of the following statements by circling the response that most accurately reflects your behavior.

1. I ask students to "think out loud."
   Daily Often Sometimes Never

2. I allow students to say "I can't."
   Daily Often Sometimes Never

3. I use learning logs/journals in my classroom.
   Daily Often Sometimes Never

4. I don't mind sharing with students how I tackle a problem/weakness.
   Daily Often Sometimes Never

5. I share the rationale/objectives of lessons/projects with students.
   Daily Often Sometimes Never

6. I make use of graphic organizers in presenting material/problems/strategies.
   Daily Often Sometimes Never

7. I require students to do some type of writing along with a reading assignment.
   Daily Often Sometimes Never

8. When I don't know an answer in class, I "think out loud" in figuring it out.
   Daily Often Sometimes Never

9. I hold open class discussions.
   Daily Often Sometimes Never

10. I see my role as a facilitator of student learning.
    Daily Often Sometimes Never

11. I teach students how to read and understand what they have read from the textbook or printed course material.
    Daily Often Sometimes Never

12. I specifically teach thinking skills in my course content.
    Daily Often Sometimes Never

13. I feel adequately prepared to teach thinking skills.
    Strongly Agree Agree Unsure Disagree Strongly Disagree

Please give any examples of how you teach or incorporate critical thinking skills in your content on the reverse side.

Appendix C

Student Survey

DIRECTIONS: Please respond to each of the following statements by circling the response that most accurately reflects your teachers' behavior.

1. Teachers ask students to "think out loud."
   Daily Often Sometimes Never

2. Teachers allow students to say "I can't."
   Daily Often Sometimes Never

3. Teachers have students use learning logs/journals in the classroom.
   Daily Often Sometimes Never

4. Teachers share with students how they tackle a problem/weakness.
   Daily Often Sometimes Never

5. Teachers share the rationale/objectives of lessons/projects with students.
   Daily Often Sometimes Never

6. Teachers make use of graphic organizers in presenting material/problems/strategies.
   Daily Often Sometimes Never

7. Teachers require students to do some type of writing along with a reading assignment.
   Daily Often Sometimes Never

8. When teachers don't know an answer in class, they "think out loud" in figuring it out.
   Daily Often Sometimes Never

9. Teachers hold open class discussions.
   Daily Often Sometimes Never

10. Teachers are responsible for students learning.
    Daily Often Sometimes Never

11. Teachers teach students how to read and understand what they have read from the textbook or printed course material.
    Daily Often Sometimes Never

12. Teachers teach thinking skills as part of the course content.
    Daily Often Sometimes Never

Appendix D

Student Survey

DIRECTIONS: Please respond to each of the following statements by circling the response that most accurately reflects your behavior.

1. I "talk to myself" (silently or out loud) when tackling a problem I'm not sure about.
   Always Sometimes Never

2. When I'm not sure of an answer on a multiple choice test, I guess randomly and move on.
   Always Sometimes Never

3. Getting ideas/suggestions from all members of my group is necessary when trying to solve a difficult or confusing problem.
   Always Sometimes Never

4. When I'm frustrated/confused, I ask myself **why**.
   Always Sometimes Never

5. I use graphic organizers in my studying.
   Always Sometimes Never

6. I find class discussion helpful.
   Always Sometimes Never

7. When I don't know an answer, I immediately ask someone else.
   Always Sometimes Never

8. It is the teacher's responsibility to make sure that I learn.
   Always Sometimes Never

9. I can see connections between things learned in one class to things learned in another class.
   Always Sometimes Never

10. When I'm not sure of an answer on a multiple choice test, I try to eliminate some of the possible answers before guessing.
    Always Sometimes Never

11. I find small group discussion helpful.
    Always Sometimes Never

12. I use only my notes or textbook when studying.
    Always Sometimes Never

13. I can see connections between things learned earlier in a course and things learned later in that course.
    Always Sometimes Never

14. Writing out ideas helps me to clarify them.
    Always Sometimes Never

15. I see my teacher as being responsible for my learning.
    Always Sometimes Never

Appendix E

Faculty Survey

DIRECTIONS: Please respond to each of the following statements by circling the response that most accurately reflects the behavior of your students.

1. Students give up quickly when the answer to a problem/question is not immediately known.
   Often Sometimes Rarely Never

2. Students, without thinking, blurt out the first answer that comes to mind.
   Often Sometimes Rarely Never

3. Students listen to each other with empathy and understanding.
   Often Sometimes Rarely Never

4. Students are open-minded and consider alternative points of view.
   Often Sometimes Rarely Never

5. Students reflect on and evaluate the quality of their own thinking.
   Often Sometimes Rarely Never

6. Students check for accuracy and precision in their written work before turning in their finished product.
   Often Sometimes Rarely Never

7. Students ask well thought out questions.
   Often Sometimes Rarely Never

8. Students draw on past knowledge and experiences to help solve new challenges.
   Often Sometimes Rarely Never

9. Students apply school-learned knowledge to real-life situations and to content areas beyond that in which it was taught.
   Often Sometimes Rarely Never

10. Students' language is confused, vague, or imprecise.
    Often Sometimes Rarely Never

11. Students are willing to take risks.
    Often Sometimes Rarely Never

12. Students use cooperative group time effectively.
    Often Sometimes Rarely Never

Appendix F

Parent Survey

DIRECTIONS: Please respond to each of the following statements by circling your most accurate response.

1. My son/daughter studies in a quiet area.
   Always Often Sometimes Never

2. There is a TV/stereo/radio in the area where my son/daughter studies.
   Always Often Sometimes Never

3. A TV/stereo/radio is on in the area where my son/daughter is studying.
   Always Often Sometimes Never

4. My son/daughter asks me for help when doing his/her homework.
   Always Often Sometimes Never

5. I feel confident helping my son/daughter with his/her homework when he/she asks.
   Always Often Sometimes Never

6. I ask my son/daughter questions about his/her homework.
   Always Often Sometimes Never

7. I ask my son/daughter to explain to me what he/she is doing in his/her homework.
   Always Often Sometimes Never

8. I ask to see my son/daughter's homework when it is completed.
   Always Often Sometimes Never

9. There is a telephone in the area where my son/daughter studies.
   Always Often Sometimes Never

10. My son/daughter makes or accepts telephone calls while he/she is studying.
    Always Often Sometimes Never

Appendix G

"THOUGHT-FULL" VOCABULARY

Analyze - to separate or break up a whole into its parts according to some plan or reason
syn. - examine, scrutinize, investigate

Anticipate - to look forward to or to be prepared for
syn. - expect, foresee, predict

Apprehend - to look forward to with dread

Argue - to give reasons for or against
syn. - convince, persuade

Assert - to declare or defend

Assume - believe to be true without supporting reasons
syn. - believe, hypothesize, postulate, presume, presuppose, suppose

Attend - to pay or fix one's attention
syn. - concentrate

Calculate - to form an opinion according to the information presented
syn. - judge, guess, conjecture, deem, suspect

Categorize - to arrange items in such a way that each possesses the particular properties, based on predetermined criteria, required to belong to a specific group
syn. - classify

Comprehend - to be aware of the meaning of
syn. - grasp, know, understand, deduce

Conceptualize - to form a thought or idea

Contemplate - to view or give attention to thoughtfully

Create - to make; to bring into being

Deduce - to derive the unknown from the known
syn. - infer, prove, reach a conclusion

Deliberate - intentional

Elaborate - to expand on an idea or object in greater detail

Empathize - to experience the feelings and thoughts of another

Estimate - to form a judgment about the worth, quantity, or significance of something - the implication being that the judgment is based on rough calculations

Flexibility - the ability to take alternate points of view or to try several different approaches to solving a problem

Induce - to combine one or more assumptions or hypotheses with available information to reach a tentative conclusion

Infer - to arrive at a conclusion that evidence, facts, or admissions point toward but do not absolutely establish

Metacogitate - being conscious of one's own thinking processes
syn. - reflect, ruminate

Predict - to formulate possible consequences of a particular event or series of experiences

Premeditate - to intend to do beforehand
syn. - plan

Problem solve - to define or describe a problem, determine the desired outcome, select possible solutions, choose strategies, test trial solutions, evaluate the outcome, and revise these steps where necessary

Rationalize - to prove to be right, just, or reasonable

Appendix H

Samples of Classroom Activities That Require Students to Reason Inductively

Problem of the Week (P.O.W.) Instructions

This is how your problem will be scored each week:

0 - NO ATTEMPT WAS MADE TO SOLVE THE PROBLEM.

2 - RESTATED THE PROBLEM, FLAWS IN UNDERSTANDING WHAT THE PROBLEM WAS ASKING, FLAWS IN EXPLANATION. SOLUTION IS NOT COMPLETE BECAUSE YOU DID NOT COMPLETE THE LOG.

4 - RESTATED THE PROBLEM, REASONABLY CLEAR EXPLANATION OF THE PROBLEM, SHOWS SOME UNDERSTANDING OF WHAT IS BEING ASKED, RESPONSE IDENTITIES MOST OF THE IMPORTANT ELEMENTS OF THE PROBLEM, ATTEMPT MADE TO COMMUNICATE THE SOLUTION PROCESS.

6 - RESTATED THE PROBLEM, CLEAR, CONCISE & CORRECT EXPLANATION OF WHAT IS BEING ASKED, INCLUDES APPROPRIATE DIAGRAM OR CHART, RESPONSE INDICATES A GOOD UNDERSTANDING OF THE MATHEMATICS INVOLVED IN SOLVING THE PROBLEM CORRECTLY.

STEPS TO FOLLOW WHEN SOLVING P.O.W.'S

1. READ THE PROBLEM SEVERAL TIMES, IF NECESSARY.

2. RESTATE THE PROBLEM IN YOUR OWN WORDS. USE THE FOLLOWING QUESTIONS AS YOUR GUIDE:
   - What is this problem asking me to find or do?
   - What important facts am I given in this problem?

3. DEVISE A PLAN.
   - Have you ever seen a problem like this before? perhaps in a different format?
   - Can you draw a picture to help you solve the problem? Make a table or chart?
   - Choose a strategy and identify it. (see the list below)

4. CARRY OUT THE PLAN AND SOLVE THE PROBLEM.
   - Show all the steps. If using "Guess and Check", show all of your guesses.
   - Document your thinking with correct language and mathematics.

5. CHECK YOUR WORK.
   - Be sure you used all of the important information.
   - Check your arithmetic.
   - Decide whether or not the answer is reasonable.
   - Include appropriate units of measure if needed (in., ft., cm, lb., $, etc.).
   - Did you answer the question that was asked?

6. LOG: WRITE ABOUT YOUR THINKING.
   - Why did you choose the strategy that you did?
   - How did you arrive at your solution? Explain how you solved the problem in words.
   - Write the solution in a complete sentence.

POSSIBLE STRATEGIES

Guess, Check, and Revise	Draw a picture	Make an organized list
Look for a pattern	Make a table/chart	Work backwards
Use logical reasoning	Act it out	Write an equation

Algebra

These problems are to be done according to the procedure for doing POW'S. Each problem should be completed on a SEPARATE sheet of loose-leaf notebook paper. These problems are to be done individually with no help from your classmates.

1. Find the three smallest **two digit** numbers that have an **odd number of factors.**

2. The Mathematics Theater has 25 seats in the first row, 27 seats in the second row, 29 seats in the third row and so on. How many seats are in the fifteenth row of the theater?

3. Take the numbers from 0 through 9 and break them up into 3 groups so that the sum in each group is the same.

4. A frog, a rabbit, and a kangaroo decide to go for a walk. The frog takes 2-foot hops, the rabbit takes 3-foot hops, and the kangaroo takes 7-foot hops. If they start their walk together, how far will they travel before all 3 have their feet on the ground at the same time?

5. If the eggs in a basket are removed two at a time, one egg will remain. If the eggs in the basket are removed three at a time, two eggs will remain. If the eggs are removed four, five, or six at a time, then three four, and five eggs will remain, respectively. If the eggs are taken out seven at a time however, no eggs will be left in the basket. Find the smallest number of eggs that could be in the basket.

Triangle Discovery Worksheet

Before opening the plastic bag, each member of the group must answer the following question individually: Do you think that given any 3 segments they can be joined at their endpoints to form a triangle?

Name _____ Answer _____

_____ _____

Now remove the straws from the bag and begin to try and form triangles using any 3 straws. Measure each straw, record its measurement in the boxes below, and then answer ***yes*** or ***no*** as to whether or not they formed a triangle. Please note that the straws may only intersect at their endpoints.

Test	1st straw	2nd straw	3rd straw	yes or no
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				

If you answered yes to every test explain why you think this will always work.

If you answered no to any test explain why you think certain cases did not work.

Write in "if-then" form what you think the theorem concerning the sides of a triangle says based on the data you collected.

_____

_____

How Did the Framers Create the Constitution?

1. Why did the Framers want to grant the power of impeachment to Congress? What might be the consequences of granting similar jurisdiction to the other two branches of government?
2. There have been very few congressional impeachments in our history. Does this suggest that impeachment is so great a power, its principal value lies in deterrence rather than in use? Explain your position.
3. One of the most important testaments of the supremacy of the legislative branch in our system of government is the power of impeachment and trial granted by the Constitution to Congress. Congress alone has the power to so discipline officials in the other branches of government. Do you believe that impeachment gives the legislative branch too much power? Why or why not?

How Did the Values and Principals Embodied in the Constitution Shape American Institutions and Practices?

1. What are the major arguments for and against judicial review?
2. How did judicial review come to be an integral part of the American constitutional system?
3. Is it appropriate in a democracy for a non-elected body to have the power of judicial review? Explain your position.

Appendix I

Samples of Classroom Activities That Require Students to Judge the Credibility of Given Situations

Algebra

These problems are to be done according to the procedure for doing POWS. Each problem should be completed on a SEPARATE sheet of loose-leaf notebook paper. These problems are to be done individually with no help from your classmates.

1. Joe and Ester were making the same salaries when the boss came in and told Joe that he was getting a 10% cut in pay. While he was there, he told Ester that she was getting a 10% raise. After six months of complaining by Joe, the boss came back and gave Joe a 10% raise and Ester a 10% cut in pay. Compare their current salaries to their original salaries after all these cuts and raises. Are they making more? Less? Explain your answer and support it with facts.

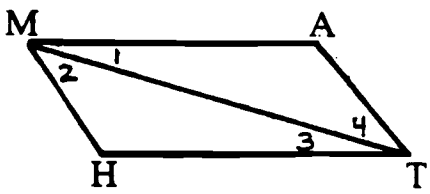
2. Your principal wants to hire you to work for her for 10 days. She will pay you either $6.00 each day for all ten days, or $0.10 on the first day and each day thereafter twice the amount from the day before. In which way would you earn the most money? Explain your thinking.

GEOMETRY

Ellen claims she has invented a new geometry theorem: ***A diagonal of a parallelogram bisects its angles.*** She gives the following proof.

GIVEN: Parallelogram $MATH$ with diagonal $\overline{MT}$

PROVE: $\overline{MT}$ bisects $\angle AMH$ and $\angle ATH$



PROOF: Since $MATH$ is a parallelogram, $\overline{MH} \cong \overline{AT}$ and $\overline{MA} \cong \overline{HT}$. Since $\overline{MT} \cong \overline{MT}$, $\Delta MHT \cong \Delta MAT$ by SSS. Therefore, $\angle 1 \cong \angle 2$ and $\angle 3 \cong \angle 4$.

1. Do you think Ellen's new theorem is true?

2. Is her proof correct? Explain your reasoning.

Sample Court Case

READ THE FOLLOWING COURT CASE AND ANSWER THE QUESTIONS THAT FOLLOW USING COMPLETE SENTENCES.

ONE TEST TOO MANY
(A True Story)

There was trouble brewing in the Vernonia School District in Vernonia, Oregon. The students knew it. The teachers knew it too. Teachers said that classes were getting harder to control. Students were acting strangely. Even some of the best athletes in the school were rumored to be taking drugs.

Finally, the school board decided to institute a system in which students who played interscholastic sports were randomly tested for drugs throughout their sports' season. The students were required to provide urine samples which were tested for evidence of amphetamines, marijuana, cocaine, and lysergic acid diethylamide (LSD).

In 1991, one family, the Actons, objected to the tests. Their son James, a seventh grader, wanted to go out for the junior high football team. His parents, Wayne and Judy, refused to consent to the test. They believed their son when he said he didn't use drugs and they didn't feel he should have to prove it. Because his parents would not sign the consent form for drug testing, James was not allowed to play on the football team.

The court battle was on. The school board argued that the tests helped deter drug use in the schools. The Actons argued that the tests violated the students' right to privacy. Students and school officials nationwide closely watched the battle as it worked its way up to the Supreme Court.

1. What did the school board assume about the athletes?

2. What information was used to justify the assumption(s)?

3. Was the information provided adequate enough to make a reasonable assumption? Explain your position.

Appendix J

Samples of Classroom Activities That Require Students to Reason Deductively

DEDUCTIVE REASONING IN ALGEBRA

Prove that if $2(x + \frac{3}{2}) = 11$, then $x = 4$.

Given: $2(x + \frac{3}{2}) = 11$

Prove: $x = 4$

STATEMENTS	REASONS
1. $2(x + \frac{3}{2}) = 11$	1.
2. $2x + 3 = 11$	2.
3. $2x = 8$	3.
4. $x = 4$	4.

Prove that if $x = -5$, then $2(x + 2) = -6$.

Given: $x = -5$

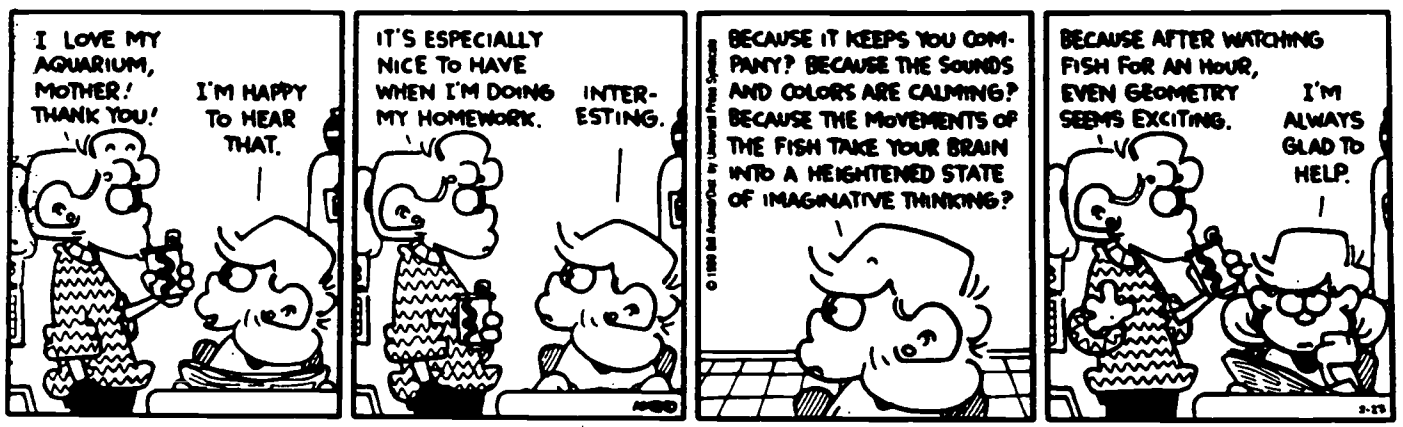
Prove: $2(x + 2) = -6$

STATEMENTS	REASONS
1. $x = -5$	1.
2. $2x = -10$	2.
3. $2x + 4 = -6$	3.
4. $2(x + 2) = -6$	4.

Cartoon Proofs

Students are given the 4 frames of a cartoon (comic strip) already cut up and in mixed-up order. They must re-sequence the frames so the comic strip makes sense. They also must indicate which comic strips contain frames in which the order of 2 or more frames can be reversed. Each frame is marked on the back and when they have decided on the correct sequencing, they list that sequence on an answer sheet that has been provided. The students work in pairs and switch comic strips with another pair when they have completed the sequencing. I use this as an introduction to the logical reasoning used in proofs.

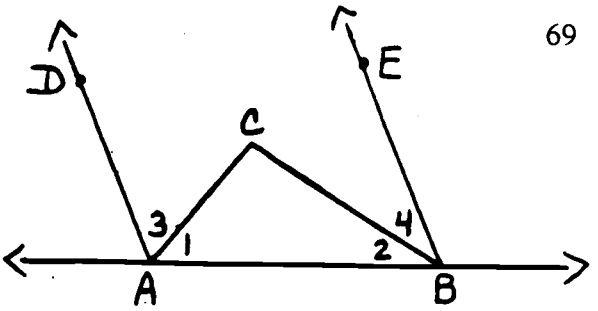
FOX TROT



EXAMPLE: These 4 frames would be cut up, mixed up and placed in an envelope. The students would have to re-sequence them in this order. None of these frames would be interchangeable.

Given: $\overline{CA}$ bisects $\angle DAB$, $\overrightarrow{AD} \parallel \overrightarrow{BE}$, $\angle 1$ & $\angle 2$ are comp.

Prove: $\overline{BC}$ bisects $\angle ABE$



The steps to the following proof are in mixed-up order. As a group, place the steps in logical order and supply a reason for each step from the list shown. Reasons may be used more than once.

Steps	Reasons
1. $m\angle DAB = m\angle 3 + m\angle 1$ $m\angle ABE = m\angle 2 + m\angle 4$	Substitution Given PSSI
2. $m\angle 1 + m\angle 2 = 90$	Def. of angle bisector Complement Thm.
3. $\angle 2 \cong \angle 4$	Def. of supplementary angles Subtraction
4. $\angle DAB$ is supp. to $\angle ABE$	Def. of complementary angles Def. of congruent angles
5. $m\angle 1 = m\angle 3$	Angle addition postulate SSIP
6. $m\angle 3 + m\angle 1 + m\angle 2 + m\angle 4 = 180$	Supplement Thm. Def. of right angle
7. $\overline{CA}$ bisects $\angle DAB$	Vertical angles thm. Linear pair postulate
8. $m\angle 1 + m\angle 4 = 90$	
9. $m\angle 3 + m\angle 4 = 90$	
10. $\overrightarrow{AD} \parallel \overrightarrow{BE}$	
11. $\overline{BC}$ bisects $\angle ABE$	
12. $\angle 1$ & $\angle 4$ are comp.	
13. $\angle 1$ & $\angle 2$ are comp.	
14. $m\angle 3 + 90 + m\angle 4 = 180$	
15. $m\angle DAB + m\angle ABE = 180$	

CREATE YOUR OWN GEOMETRY

PAGE 1: Your name and date in the upper right hand corner. The name of your Geometry should be centered. After your name, list your postulates. The postulates must be in "if-then" or "if and only if" form. Use some of each. You must have at least 8 postulates. Include postulates that you won't use in your proof also.

PAGE 2: Write the statement (theorem) that you are going to prove at the top of the page.

PAGE 3: Write the "Given" and "Prove" for your theorem and then prove it on this page. In other words, supply me with an answer key for your problem. Your proof must be at least 6 steps. Don't write the theorem so that the steps follow from postulate 1 to 2 to 3, etc. Use the two-column deductive proof method. Make it challenging since your theorem will be given to someone else to prove.

Please type and staple it together.

Have fun and be creative!

Example:

Page 1:

Tailor-ometry

Postulates:

1. I can tailor if and only if I can measure.
2. If I can make clothes, then I can sew.
3. If I can tailor, then I can make a career of it.
4. If I can measure, then I can draw.
5. If I can sew it together, then I can make clothes.
6. I can draw if and only if I am an artist.
7. If I can put it together orderly, then I can sew it together.
8. If I can draw, then I can cut out the right measurements of cloth.
9. If I can measure, then I can use a ruler.
10. If I can cut out the right measurements of cloth, then I can put it together orderly.

Page 2:

Theorem: If I can tailor, then I can make clothes.

Page 3:

Given: I can tailor.
Prove: I can make clothes.

Statements	Reasons
1. I can tailor.	1. given
2. I can measure.	2. Postulate 1
3. I can draw.	3. Postulate 4
4. I can cut out the right measurements of cloth.	4. Postulate 8
5. I can put it together orderly.	5. Postulate 10
6. I can sew it together.	6. Postulate 7
7. I can make clothes.	7. Postulate 5

Student Work Sample

Alien-ometry

Postulates:

1. I live on Mars iff I don't breathe oxygen.
2. I am green iff I have 4 eyes.
3. If I have 4 legs, then I have 16 toes.
4. If I am green, then I don't breathe oxygen.
5. I have blue eyes iff I am green.
6. If I have 3 arms, then I have 4 legs.
7. If I am an alien, then I have 3 arms.
8. If I don't breathe oxygen, then I live in outer space.
9. If I am an alien, then I like vegetables.
10. I have 4 eyes iff I have 4 legs.
11. If I have 3 arms, then I have 9 fingers.

Theorem: If I am an alien, then I live in outer space.

Given: I am an alien

Prove: I live in outer space

STATEMENT	REASON
1. I am an alien	1. Given
2. I have 3 arms	2. Postulate 7
3. I have 4 legs	3. Postulate 6
4. I have 4 eyes	4. Postulate 10
5. I am green	5. Postulate 2
6. I don't breathe oxygen	6. Postulate 4
7. I live in outer space	7. Postulate 8

How To Draw and Test Conclusions

A syllogism may show either good reasoning or faulty reasoning. Good reasoning is thinking that makes sense and that leads to workable conclusions. Faulty reasoning, on the other hand, leads to poor conclusions and solutions that don't work well.

A syllogism is good if it has all three of the following characteristics:

1. The two premises are facts or inferences that have always been true and probably always will be true. (Example: Every human being is born and eventually dies.)
2. There is a logical connection between the two premises and the conclusion. The two premises should lead you directly to the conclusion.
3. The conclusion must be true.

If any of these conditions is missing, the syllogism is faulty and the conclusion may also be a mistake. Good critical thinking is always based on sound reasoning. Faulty reasoning leads us to mistakes in our thoughts and actions.

Here is an example of a syllogism:

Premise 1: All large men are football players.

Premise 2: John is a large man.

Conclusion: Therefore, John is a football player.

Is this a good syllogism? No, because the first premise is not true. All large men are not football players. That means that the conclusion is automatically questionable. In this case, we cannot tell whether John is a football player or not.

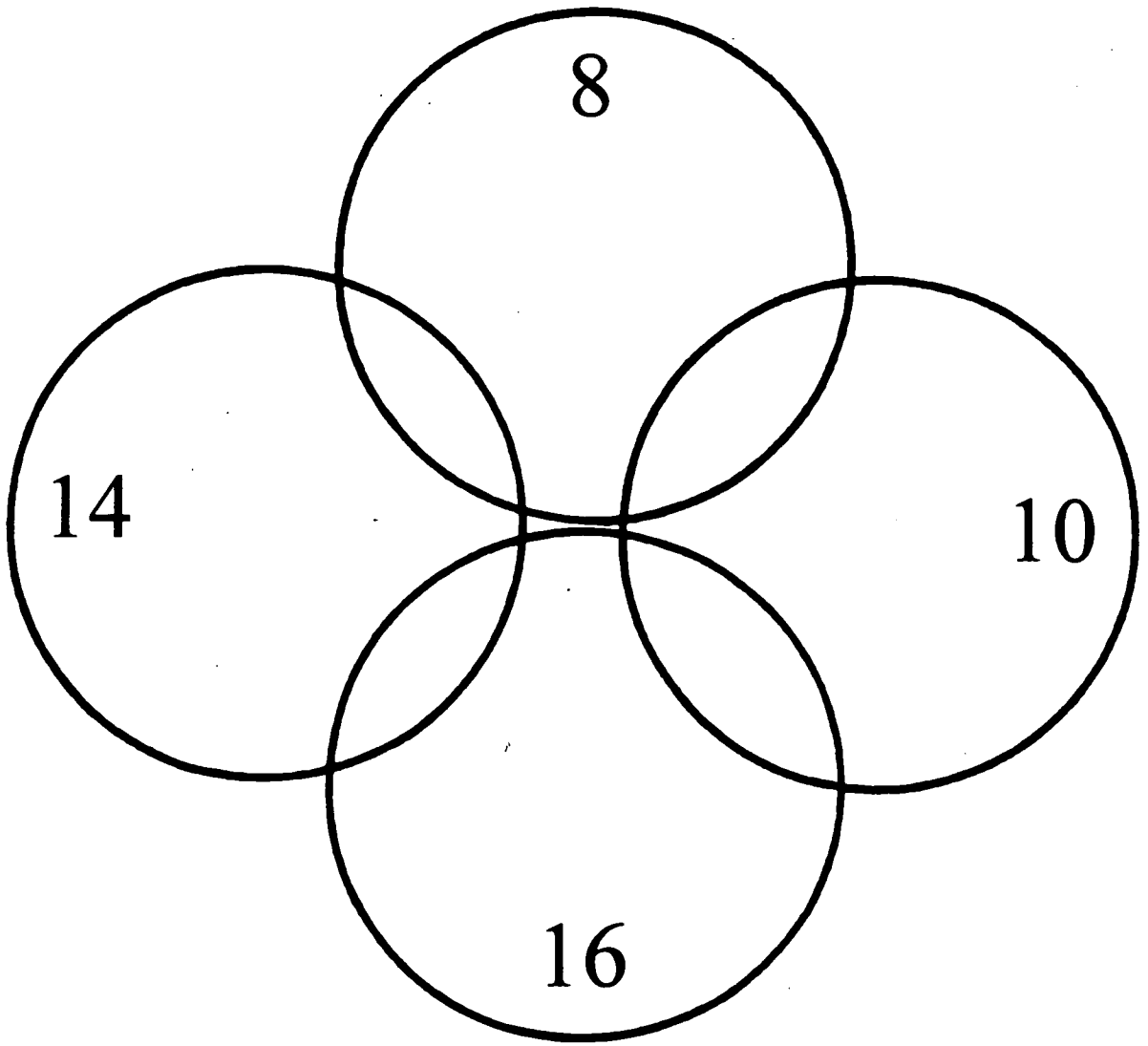
ASSIGNMENT: Write one **good** syllogism that argues your point of view. Have at least 3 premises.

Appendix K

Samples of Classroom Activities That Require Students to Recognize the Validity of Assumptions

Algebra

Put a different **odd** number in each of the four circle overlaps so that the sum of the three numbers in each circle is 24. You must find 5 different solutions!



ASSUMPTIONS - CAN WE OR CAN'T WE?

Determine whether each relationship can be <u>assumed</u> from the figure. Answer *yes* or *no* and explain your reasoning.

1. $\angle$ BFE is a right angle.

2. $\overline{AD} \perp \overline{AC}$

3. $\overline{ED} \cong \overline{EC}$

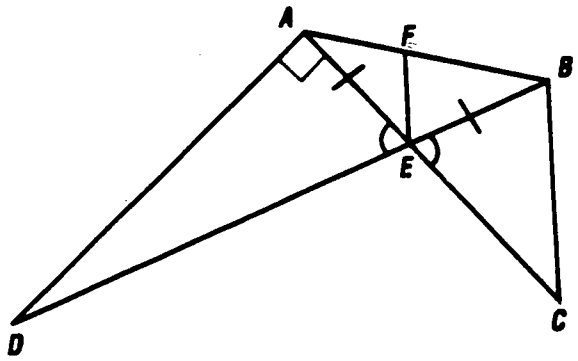
4. F is the midpoint of $\overline{AB}$.

5. $\angle$ AEF and $\angle$ BEF are congruent.

6. AC = AE + EC

7. $\overline{BC} \perp \overline{BD}$

8. $\angle$ AED $\cong \angle$ BEC



9. Identify another <u>invalid</u> assumption that a student may make when working with this figure.

AN ANALYSIS OF GEORGE WASHINGTON

Looking at several points of view is very important when trying to get an accurate understanding of history. It is also important to understand what can and cannot be assumed as true.

ASSIGNMENT: Find at least 3 primary sources that mention traits about George Washington's personality. After you find the primary sources, answer the following question: Was George Washington a "man for all seasons"? Explain your reasoning.

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